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Characteristics and Variants of Socio-technical Transitions

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Abstract

Processes of socio-technical change that are triggered by new technological opportunities do not occur as radical fractures over short periods of time, subsequently leading to new periods of technological, institutional and organizational continuity. What appears—after ten, twenty, or thirty years—to be radical socio-technical change is in fact the result of longer search and restructuring processes, which are influenced by a number of related technological and socio-economic changes. Once these changes accumulate, they then lead to substantial adjustments within the technological, institutional and (inter-) organizational foundations of a society, the economy, or within a sector. How can an analysis of such processes of radical as well as gradual change be performed? What mechanisms are involved in their occurrence, which patterns do they follow and what variations do they assume? Against the background of technology-induced change within economic sectors, this paper develops a concept of gradual socio-technical transformation. 'Transformation' means: change resulting in the radical realignment of a field, by which both its technological profile and the connected social coordinates are significantly modified. 'Gradual', on the other hand, emphasizes the fundamental procedural peculiarity of such changes, which essentially occur by degrees as an accumulation of numerous transformation-related impulses extending over a longer period of time. The concept provides concrete tools for analyzing and classifying exceptional periods of substantial socio-technical change.

Zusammenfassung

Durch neue technologische Möglichkeiten angestoßene Prozesse soziotechnischen Wandels verlaufen nicht als radikale Brüche in kurzen Fristen, die schnell in eine neue Periode technologischer, institutioneller und organisationaler Kontinuität münden. Das, was nach zehn, zwanzig oder dreißig Jahren als radikaler soziotechnischer Umbruch erscheint, ist vielmehr das Ergebnis längerer Such- und Neustrukturierungsprozesse, die durch eine Vielzahl aufeinander bezogener technologischer und sozioökonomischer Veränderungen geprägt werden. Erst in ihrer Kumulation führen diese Veränderungen zu substanziellen Erneuerungen der technologischen, institutionellen und (inter-) organisationalen Grundlagen der Gesellschaft, der Wirtschaft oder eines Sektors. Wie lassen sich solche Prozesse ebenso radikalen wie sukzessiven Wandels analysieren? Über welche Formen vollziehen sie sich, welche Verlaufsmuster und Varianten können sie annehmen? Vor dem Hintergrund des durch neue Technologien angestoßenen Wandels von Wirtschaftssektoren wird in diesem Aufsatz ein Konzept gradueller sozio-technischer Transformation entwickelt, mit dem sich die vielschrittigen, oft erratischen und nichtlinearen Prozesse soziotechnischen Wandels analysieren und strukturieren lassen, die sich erst mit der Zeit zu substanziellen sektoralen Neuausrichtungen verdichten. ‚Transformation' heißt: Im Ergebnis radikale Neuausrichtung eines Feldes, durch die sich sowohl dessen technologisches Profil als auch – damit verbunden – dessen soziale Koordinaten substanziell verändern. ‚Graduell' betont demgegenüber die wesentliche prozessuale Eigenheit derartiger Umbrüche, die sich grundsätzlich schrittweise, als Kumulation zahlreicher Transformationsimpulse vollziehen und über einen längeren Zeitraum erstrecken.

Contents

1 Introduction

Since the end of the 1970s we have found ourselves in a period of fundamental socio-technical change. At its center are, without a doubt, the widespread dissemination and lasting radical advancement of digital information, communication and network technologies. Moreover, with genetic engineering a second cluster of new technologies was established that made possible targeted recombination and changes to varying types of natural processes.

There are two typical features to such periods of fundamental socio-technical change: First, they can be characterized as notable breaks or turning points. They embody far-reaching transformations of socio-technical structures and regulations, which had been stable over a comparatively lengthy period of time, and had, until then, influenced broad portions of the economy and society. Second, at the same time, such periods can be described as temporally protracted and gradual processes of restructuring. They are defined by longer phases that are influenced by sustained high-levels of innovation dynamics with radical new or further developments within knowledge and technologies. Furthermore, they can be distinguished by the accompanying search for fitting organizational forms, patterns of interactions, structures and regulations. That which after ten, twenty, or thirty years appears to be radical socio-technical change, is in fact the result of longer search and restructuring processes. These are impacted by a number of more or less strongly related transformations. It is first when these transformations accumulate that they then lead to a substantial modernization of the technological, institutional and (inter-)organizational foundations of society, the economy or of an economic sector.

How do sustained socio-technical changes come about? And what patterns do they adopt? Answering these questions are central to this paper's line of reasoning, in which the processes of far-reaching socio-technical change will be conceptualized as constituting radical shifts proceeding in a gradual way.

Within the literature on the economics of innovation, such processes have been described since the end of the 1980s as *periods of mismatch*. These are characterized by longer-lasting phases of experimenting with and the interest-led examination of new technologies and by the search for modified organizational patterns, structures and regulations, which are matched to the new technologies (Freeman and Perez 1988; Dosi et al. 1988; Kitschelt 1991; similarly Dolata 1992: above all 215–241; Rip and Kemp 1998; Kemp et al. 2001). Such evaluations, which are the starting point for the following considerations, admittedly remain vague in answering the question of what concrete mechanisms and forms are characteristic to such periods of change or in regard to the typical patterns or variations that these may adopt.

Newer research on socio-technical change is in that sense somewhat more concrete. For several years now it has attempted to identify different *transition contexts*—and

building upon this—to devise and delineate alternative *socio-technical transition pathways* (Smith et al. 2005; Geels and Schot 2007; Geels and Kemp 2007; Dolata 2009). At the core of this conceptualization is the idea that socio-technical transformation processes occur via an interplay between precisely calculated technological pressure to change and distinct social opportunities for observing, acting upon and manipulating this pressure within the affected field. This is the first starting point for the following set of considerations.

The second starting point is constituted by recent research on institutional change within developed capitalist societies. This is above all typified by the work of Kathleen Thelen and Wolfgang Streeck (Thelen 2003; Streeck and Thelen 2005; Mahoney and Thelen 2010). This field of research emphasizes that processes of serious institutional change cannot, as a rule, be characterized as short-term radical changes, but occur incrementally, requiring longer periods of time. They are placed in concrete terms via distinct modes of gradual transformation, through which the existing regulation structures within capitalist societies are shifted by degrees, moving towards a new model of political-economic institutions.

In what follows, I will further develop these considerations and establish a *concept of gradual socio-technical transformation*. I will do so against the background of changes to economic sectors that are triggered by new technologies. This concept will then be used to analyze and structure the multi-phased, often erratic and non-linear processes of socio-technical change: only with time do these consolidate into substantial sectoral adjustments.

This concept of gradual socio-technical change will be laid out in three steps. The article first begins with evidence from two empirical case studies: the transformation of the pharmaceutical industry driven forward by genetic engineering, and the transformation of the music industry caused by the Internet (*section 2*). These cases serve to introduce the idea of gradual transformation as a largely typical form of substantial socio-technical change. This is followed by a concise summary and evaluation of the newer concepts related to institutional change. At the center of this is the elaboration of "modes of *gradual transformative change* of modern political-economic institutions" (Streeck and Thelen 2005: 2; emphasis in the original) (*section 3*). These form the foundation for my own considerations that are expanded upon in *section 4* to create an analytical concept of gradual socio-technical transformation. At that point, I will specify the mechanisms implemented in these processes and the patterns and variants that may be adopted. In *section 5*, I will provide an overview of the core elements of this concept and reflect on how best to conduct pragmatic research on the subject.

2 Gradual Transformations and Substantial Change: An Empirical Approach

I will begin with two brief empirical reconstructions. Both cases should lead up to the idea that even serious sectoral change generally forges ahead via gradual, often erratic and initially ambiguous transformations.

2.1 Case 1: The Pharmaceutical Sector and Genetic Engineering

In the last thirty years genetic engineering has provoked serious changes primarily within the pharmaceutical sector. It has led to a new alignment of the sector's technological profile and knowledge basis. Besides chemical syntheses, methods and procedures from genetic engineering have become crucial new instruments for research and production. It has changed the market for pharmaceuticals where genetically engineered therapeutic agents, vaccines and diagnostic aids have gained in importance since the middle of the 1980s. Genetic engineering spurred significant adjustments in industry structures and sectoral patterns of interaction: especially through the establishment of new biotechnology start-ups and with the intensification of partnerships between pharmaceutical companies, start-up companies and research institutes. And finally, it led to substantial changes within the regulatory framework of the sector, which are above all reflected in self-contained legal regulations and directives for genetic engineering.

The sectoral transformation that was shaped by these processes did not occur abruptly and over a short period of time. Instead it involved a longer adjustment process that began in the middle of the 1970s and extended well into the 1990s (Dolata 1996, 2003; Henderson et al. 1999; Barben 2007). Nor was it characterized by a radical displacement or disintegration of the existing socio-technical profile. It was, however, defined by selective revisions, innovative combinations and substantial expansions of the guiding principles and technologies; the organizational structures and patterns of interaction; and of the structural and institutional framework.

The origin for this transformation was provided in the second half of the 1970s with the founding of biotechnology start-ups in the USA. These firms were responsible for initiating the commercial exploitation of the new technologies. The pharmaceutical companies themselves, with few exceptions, approached this new field of technology hesitantly. Only during the 1980s did they undergo measured strategic and organizational repositioning. During that decade, they did not in any way undertake a complete revision of the research procedures that centered upon chemical syntheses. What they did however begin was a gradual expansion into genetic engineering methods and practices. Little by little, they became involved in what were, for them, new modes of cooperative research. These modes extended beyond what had previously been in-house oriented research and development activities to encompass ex-

tensive networks of cooperation with start-up companies and academic research institutions.

Biotechnology start-ups, which were previously unheard of in the pharmaceutical sector, were able to establish themselves between the end of the 1970s and the first half of the 1990s. These companies developed into important drivers of innovation over the course of the 1980s and have become, thanks to their flexible research structures, indispensable partners for pharmaceutical companies. Nevertheless, in 2006 there were only two biotechnologies companies among the twenty pharmaceutical firms with the highest turnover rates: Amgen (ranked number 14) and Genetech (ranked number 19)—which entirely belongs to Hoffman-LaRoche (Dolata 2007). In contrast, the majority of the 4000 biotechnology companies from North America and Western Europe have not succeeded in extending beyond the status of suppliers, service providers and research-intensive partners for pharmaceutical companies (Roijakkers and Hagedoorn 2006). Although biotechnology companies have been able to expand upon the range of actors and forms of interaction within the sector, they have not replaced the classical pharmaceutical companies as the dominant core actors.

Genetic engineering did not just substantially change the industrial structure and the patterns of interaction within the sector. It also introduced new products and made an enduring impact on the pharmaceuticals market. In 1982 human insulin became the first genetically engineered therapeutic on the market. Twenty-five years later, worldwide there were several hundred pharmaceuticals on the market that are produced with active ingredients gained through genetic engineering. At least a dozen among those were blockbuster drugs, with annual earnings between one- and four-billion US dollars. But, even in the middle of the 2000s, conventional, chemically synthesized therapeutic agents still dominated the global pharmaceuticals market. In fact, in 2006 only about 10 percent of the then US$ 643 billion in global pharmaceutical sales resulted from drugs made with active agents gained through genetic engineering. Bioengineered medicines have not supplanted chemically synthesized drugs; what they have done is gradually supplement these drugs and expand the product portfolio (Dolata 2007). This equally applies to the sector's paradigmatic research orientation. Of course, since the 1980s it has become impossible to imagine pharmaceutical research without the central methods and processes taken from biotechnology and genetic engineering. They have, however, not replaced the established research methods and production processes such as screening methods and chemical syntheses, which are also subject to dynamic technological changes. In lieu of this, what is common are innovative combinations of newer and older techniques (Drews 1999: 71–115).

Ultimately, a self-contained legal and regulatory framework for research, development and production was developed within the large capitalist countries and the Eu-

ropean Union, appearing alongside conventional pharmaceutical law. Even this process was protracted, moving from one country to the next, exhibiting different points of emphasis in each. Extending from the end of the 1970s well into the 1990s, this process was accompanied by controversial political and social debates regarding the meaning or the organization of these new regulatory frameworks. In Germany such discussions began as early as the late 1970s and first led in 1990 to a law on genetic engineering. By 1993 this law was already subjected to substantial amendments. Negotiations, which occurred simultaneously within the framework of the European Union, were also first solidified in 1990 with the enactment of several directives aimed at regulating the usage of genetic engineering within the Member States (Schenek 1995; Bandelow 1999). Characteristic of the developments in the legal-regulatory sphere pertaining to this new field of technology were not only the lengthy discussions leading up to legislation but also, until more recently, the repeated adjustments to this framework.

As a whole, the pharmaceutical sector's process of transformation was distinguished not by radical disintegration, the dissolution or displacement of existing competences, technological profiles, actors, structures and institutions. Rather, it was defined by substantial revisions, recombinations and extensions, the interplay of which has over time nonetheless seriously changed the sector.

2.2 Case 2: The Music Industry and the Internet

The Internet, as a multi-purpose technology, has developed at a rapid rate since the 1990s into a new, ubiquitous information, communication and distribution medium. The classic media industries—the music and film industries, the book trade or the newspaper and magazine markets—are fields that are especially threatened by the Internet and the online migration of digital and compressible contents (Küng et al. 2008). The music industry was the first among these fields to be affected. The technological profile, the markets and distribution patterns of the sector have, for several years now, shifted away from physical music recordings towards digital music files. Such media are no longer sold exclusively via retail stores, but are instead also sold online. Patterns of interactions, competition and power structures have been re-sorted due to the penetration of external actors into the sector. Consumer behavior, above all on the part of teenage listeners, has been significantly changed by the ease and non-commercial exchange of digital music in the direction of free file sharing. Based on these changed conditions, both established and newer commercial actors find themselves searching for economically sustainable business and profit models based on digital music. Furthermore, they are also seeking adjustments to the legal and use relationships in response to recent developments (Peitz and Waelbroek 2006; Tschmuck 2006).

Although the transformation of the music sector developed in an extraordinarily dynamic way, and the Internet had a lasting effect on the sector's foundations, the transformation in fact involved a longer phase, arguably lasting up to fifteen years. This phase, which began at the end of the 1990s and now a decade later is still not yet complete, was indeed crisis-laden. Until the middle of the 2000s, this phase was characterized by a boom in the non-commercial exchange of music via peer-to-peer networks, by large quantities of file sharing between music consumers, and by the first commercial downloadable offerings, especially through the Apple iTunes store. It was influenced as well as by the unsuccessful attempts made by the music companies to defend and maintain their established business in the Internet age (Dolata 2011; Burkhart and McCourt 2006).

In the second half of the decade, business with digital music files from the Internet began to take shape and has by now grown to significant proportions. However, the share of sales made in the large music markets did not change abruptly, shifting incrementally from physical recordings (primarily CDs) to digital music (downloads, online-subscriptions, ringtones). In 2009, despite an enormous increase in the sale of digital music, 59 percent of annual sales in the USA still comprised physical recording purchases, in Germany annual sales of physical recordings were at 91 percent (RIAA 2010; Bundesverband Musikindustrie 2010). Furthermore, in 2010 the proportion of record companies' global revenues from digital channels was 29 percent (IFPI 2011: 5). Even when the tables are turning in digital music's favor, it is still impossible to speak of a radical replacement of CDs by digital music. Physical music recordings and digital music will continue to coexist for several years to come and will be marketed parallel to one another.

Since the middle of the 2000s, the music companies have also begun to get involved with the changes within their branch, to reorganize their business and to experiment with new Internet-based business models. Their efforts include experiments with parallel marketing of both music recordings and music files; with the sales of music via online-subscriptions; with the free supply of music refinanced through advertisements, tours, or mobile phone sales; and with full-package marketing of musicians signed to their labels (IFPI 2009). These organizational changes followed as a result of an increased sense of insecurity regarding further developments within the music business and, as such, were in no way finished as of 2011. For the next few years it will remain unclear as to which Internet-based business and profit model will prove to be sustainable.

The commercialization of digital music calls not only for testing new business models and corresponding organizational restructuring, but also for a far-reaching realignment of the legal and use frameworks. Up until the middle of the 2000s, these were tailored to physical music recordings. Such institutional readjustments are expensive in terms of time and money, since they must be negotiated, tested and decid-

ed upon by a larger number of actors with at times greatly diverging interests. This range of actors includes music companies, musicians signed to record label contracts, the organizations in charge of use and copyrights, as well as online digital music providers. A legal and use framework that matches the new business form cannot be developed in a singular attempt, but evolves via a series of ongoing changes that are also tied to subversive Internet actors who continually call the process into question (Rodriguez et al. 2007).

Finally, the transformation in the music sector is influenced by changes in the figurations of actors, competitive conditions and power structures. In this process, there are inevitably winners and losers, but certainly even in this case there is no comprehensive substitution of players. The music companies and the large retail chains, that constituted the core of the 'old' music industry, are still there. From the middle of the 2000s, these core actors began to expand their businesses to include digital music. For all intents and purposes, they could remain important actors in a newly structured music industry in their capacities as producers, global promoters, holders of rights and established distributors. In the meantime, they have grappled with a number of strong new actors. These have turned out to be more than just negotiating and contractual partners who are on an equal footing with the music companies; they are also challengers for the large retail chains. These challengers come from the computer industry (Apple), the telecommunications industry (T-Online), the mobile phone industry (Vodafone, Nokia), or from retail (Amazon, Walmart). They dominate Internet-based digital music distribution with their offerings and are the central drivers behind the web-based music business. Characteristic of this case is a substantial expansion of the spectrum of actors, which is accompanied by the restructuring of patterns of interaction and power relations within the sector (Dolata 2011).

Without a doubt, all of this accounts for a radical transformation of the music industry that involves a longer process of sectoral readjustment and reorganization. It is characterized by a diversification of marketing methods; the formation of new business forms; the redefining of the institutional framework; the differentiation of the supporting actor spectrum; and by accompanying changes to sectoral structures of power and influence.

3 In Between Continuity and Change: Institutionalism's Attempts at Eliminating a Blind Spot

The examples described herein are representative of processes of substantial sectoral change. The factors that were highlighted for the cases of the pharmaceutical and music sectors could also be shown to exist in a similar way in instances of the Internet's infiltration into other media sectors—such as in film, the book trade, magazines and newspapers (Küng et al. 2008; Currah 2006, 2009; OECD 2010; Schrape 2010, 2011; e-business watch 2005a). It also applies to the introduction of E-Commerce in varying aspects of trade (Riehm et al. 2003); to the transition from large computers to networked microcomputers within the computer industry in the 1980s (Bresnahan and Malerba 1999; Kenney and Curry 2001); or to the wave of digitalization and deregulation of the telecommunications infrastructures that were implemented in the 1980s and 1990s (Werle 1990; Schneider 2001; Mayntz 2009). Technology-induced sectoral change is, evidently, not characterized by singular and eruptive transformations in the short term that quickly lead to a new phase of stability typified by relatively marginal further adjustments. Nor is sectoral change, as a rule, shaped by the explosion, collapse or drastic exchange of existing technologies, structures, institutions, and actors. On the contrary, what are common are in fact longer phases of discontinuity and adjustment that last between one and two decades. Within this period a sector moves towards a new, dominant socio-technical design after passing through a series of gradual transformations. Moreover, this new design is then continually put to the test by sustained technological innovation dynamics.

It is impossible to adequately measure the actual course of technology-induced sectoral change by using dichotomous typing, that simply differentiates between longer periods of stability and the infrequent abrupt and drastic fractures caused by exogenous shocks. The sort of ideas that are widespread within institutionalism and path dependency conceptualizations actually serve to hide the interesting field between stability on the one hand and radical changes in a system on the other.[1]

In the meantime, there are a number of contributions that have distanced themselves from this simplified alternative between radical change and long-lasting continuity and which have begun to survey the uninvestigated field in-between (Thelen 2003; Streeck and Thelen 2005; Hall and Thelen 2009; Mahoney and Thelen 2010; Djelic and Quack 2003, 2007; Quack 2005; Campbell 2004, 2006; King 2007). In most cas-

[1] The idea of phases of sustained continuity that are periodically disrupted by radical changes is widespread in institutionalist and path dependency theories. Their central claim is as follows: "Path-dependent equilibrium is periodically ruptured by radical change, making for sudden bends in the path of history" (Pempel 1998: 3; Krasner 1988). This serves to raise the bar for institutional and structural change: beyond radical change there is in essence only continuity. It is then impossible to analyze or interpret processes of cumulative gradual change that have transformative results (for a critique thereof see Greenwood and Hinings 1996; Thelen 2003; Beyer 2006; Walgenbach and Meyer 2008).

es these contributions deal with subject matter far from the topics handled here. What they do offer, however, are interesting conceptual considerations that can be picked up and further developed when conducting investigations of technology-induced change.

The latter is particularly applicable to the idea of gradual institutional transformation and the search for "modes of gradual but nevertheless transformative change", both of which were developed by Kathleen Thelen (Streeck and Thelen 2005: 19; Thelen 2003; Mahoney and Thelen 2010). The observable institutional change towards liberalization that has occurred in highly developed capitalistic societies since the 1980s is the background against which she and her co-authors developed their considerations. The essential characteristic of this change is that it extends over a longer period of time. In addition to this, it is shaped by a number of gradual, subtle and self-reinforcing transformations, not by abrupt breaking points or radical fractures. "The current transformation of modern capitalism (…) unfolds by and large incrementally, without dramatic disruptions like the wars and revolutions that were characteristic of the first half of the twentieth century" (Streeck and Thelen 2005: 4). Due to their accumulation over time these gradual transformations have certainly remained anything other than unimportant. In the process of their accumulation—and this is the second fundamental characteristic of such transformations—they have gradually led to substantial changes within the institutional foundations of the capitalist society. "Ongoing change and its accumulating results increasingly suggest that the current process of liberalization involves a major recasting of the system of democratic capitalism as we know it, issuing in a social order dissociated from fundamental assumptions of social integration and political-economic conflict resolution that underlay the construction of the postwar settlement after 1945" (Streeck and Thelen 2005: 5; for greater details regarding the transformation of German capitalism see Streeck 2009: 31–89). Similar to the intersection of substantial socio-technical change dealt with herein, radical fractures that occur in the short term are not what are emphasized as being typical for the serious changes of today's capitalistic society. Just the opposite, it is "a type of change that is *slow and transformative at the same time*" (Streeck and Thelen 2005: 15; emphasis in the original).

In order to better understand and describe this type of change, one must first identify the typical modes that may be involved in its implementation: "modes of change going beyond the familiar but perhaps ultimately quite rare cases of institutional 'breakdown' or wholesale replacement" (Thelen 2003: 221). Kathleen Thelen and Wolfgang Streeck have attempted just that. On the basis of empirical case studies they introduced what are, in their opinion, five relevant *modes of gradual transformation*, through which substantial institutional changes can occur over time (Thelen 2003; Streeck and Thelen 2005: 18–33; Mahoney and Thelen 2010):

- *Layering*. Serious change can first occur once new elements are added to existing institutional arrangements and have gradually changed these arrangements' substance through their own rise in importance. Established institutions are, in this case, not fundamentally called into question, but are transformed through amendments and extensions in the form of new rules, norms and orientations. Over time, these amendments increase in significance.
- *Conversion*. Second, the goals, functions and the determination of aims of existing institutions can also be adjusted and reoriented in response to new challenges and shifted interests. In this case, institutional change takes place through modifications to the existing arrangements, not through their expansion and accumulation by means of new elements. "Institutions designed with one set of goals in mind are redirected to other ends" (Thelen 2003: 228).
- *Displacement*. Third, the institutional framework of a field or system can also change when initially subordinated regulations and orientations, which emerge on its fringes, increase in importance over time, become dominant and gradually replace older pre-existing ones. In this case, change does not occur through expansions or modifications to *established* institutions, but on the contrary through a rise in the importance of completely new and *alternative* institutional arrangements. These are placed in opposition to the pre-existing institutions and are supported by an expansion in the set of actors.
- *Drift.* Fourth, in time, established institutions can lose relevance, erode and deteriorate. This happens when modifications to the political, economic and social frameworks are not recognized in time, and adjustments in response to these conditions remain missing or are insufficient. Gradual change in this case refers to a steady decrease in the importance of established institutions due to their inability to adapt.
- *Exhaustion*. While an institution in cases of *drift* formally remains in existence, even though it has become less important, the fifth variant of institutional change is characterized by the gradual collapse and failure of the institution. Collapse occurs when its intended purpose has been exhausted and becomes obsolete. This is not an instance of decline due to the inability to adapt; the affected institutions have simply become superfluous.

4 Radical Change as Gradual Transformation: Characteristics and Variants of Socio-technical Changes

With the help of these modes it is possible to test varying cases of substantial change for plausibility. Substantial change is not the short-term result of radical fractures but instead the outcome of a variety of gradual transformations.[2] This is what makes this concept so interesting for studying socio-technical transformations. When considering larger socio-technical changes as embodying transformation processes that extend, as a rule, over a period of fifteen, twenty and at times thirty years, then one promptly poses the question of how such processes actually proceed. Which modes and variants are involved in developing new socio-technical realities? This clearly does not occur in the form of a rapid and clear-cut collapse of the existing socio-technical order nor in the form of a radical and frictionless replacement of the established technological, organizational and institutional settings.

How do socio-technical periods of transformation occur? Is it possible to differentiate analytically between common variants? The concept borrowed from Thelen and Streeck, and the modes of gradual change that they introduced, provide the first indicators necessary for answering these questions. Yet these remain insufficient in more ways than one.

The interrelation that is of interest here does not just involve the transformation of social institutions, which are the phenomenon at the foreground of Streeck and Thelen's research. It comprises the interplay between far-reaching technological changes, whose (potential) radicalness is unquestioned, and social processes of restructuring that are instigated by and interwoven in one another. Transformation processes, such as the ones that are debated here, do not occur "almost imperceptibly" (Streeck 2009: 15) and clearly extend beyond institutional changes within a field. Accordingly, focusing on the processes of incremental institutional change is overly narrow in two specific aspects related to the subject matter at hand. The socio-technical fields that are of interest here are (1.) under massive amounts of pressure to change, in parts this is even radical in nature; and this pressure (2.) extends to both the technological basics of the socio-technical fields and—this is inseparably linked to—its structural, institutional and organizational foundations.

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[2] Listing the varying forms of gradual transformation retains a trace of arbitrariness. Thus, without any explanation, the modus *exhaustion* is left out of the above-mentioned article by Mahoney and Thelen (2010). Why? Wolfgang Streeck (2009: 15) treats the developed categories in a decidedly casual manner: "We suggested a few more types of slow change, in particular 'displacement', 'drift', and 'exhaustion'. Time will tell which of these will survive, and whether they were more than elaborations on the two original Thelen models". What remains is no more than an empirical plausibility that between continuity and fracture there is, in fact, a third category: "In any case, they may be regarded as an attempt to describe in empirically grounded institutionalist language 'dialectical' tendencies in social institutions undermining themselves in the course of their normal operation—the opposite of path-dependent reproduction".

Moreover, for the purposes of completely reconstructing a period of change and to precisely describe its type, it is not enough to refer back to one of the named modes of gradual transformation. It is fairly improbable that longer-lasting periods of change, with all of their heterogeneous influencing factors, extended processes of searching and interest-led debates, could be influenced or characterized alone or primarily by one of the described forms of gradual transformation. What is fundamentally more likely is that more than one mode appears in such periods of mismatch. These either reciprocally reinforce or may compete with one another. It is also likely that their meaning and relationship to another can change significantly over time. Distinct variations of institutional or, in this case, socio-technical transformations can be identified and delineated by type primarily by referencing the specific manner of interactions between varying modes of gradual change. Such types of combinations have yet to be contemplated or even tested by proponents of the concept.

In the following I will discuss and refine these questions on how substantial socio-technical change can be conceptualized as a gradual transformation. Thereby I will first explain the meaning of the idea that gradual transformation is the typical form of substantial socio-technical change (*specification 1*). Following this, I will give reasons for why socio-technical change, as a rule, is characterized by the combination of varying modes of gradual transformation (s*pecification 2*). Against this background, I will identify four typical variants of gradual transformation that result from particular combinations (*specification 3*).

4.1 Specification 1: Socio-technical Changes as Gradual Transformation

In the case at hand, the starting points for substantial change are, as already stated, not social phenomena such as the liberalization dynamics central to the work of Thelen and Streeck. On the contrary, they are technologies, more precisely: new technological opportunities, which can no longer be easily framed within the existing socio-economic structures, institutions or organizational forms of a sector. Instead they instigate far-reaching socio-technical adjustments. The fact that these occur gradually and over a longer period of time has technological as well as social reasons.

Larger *technological changes* are always marked by historically identifiable turning points or leaps forward in development. Examples of this are the change from super- to microcomputers at the end of the 1970s; the digitalization of the telecommunications infrastructures in the first half of the 1980s; the breakthrough of methods and processes from genetic engineering in the second half of the 1970s; or the boom of the Internet as a new information and communications platform starting in the second half of the 1990s. These turnings points do not, however, lead in the short term to new and stable technological paths of development.

This depends, to a certain degree, on the ambiguous character of new technological opportunities during their formative phase. It is often initially unclear what can concretely be done with them. They are experimented with and fitting applications are sought. These must then be tested and organized according to specific circumstances and are further developed or reinterpreted. To begin with they stimulate the creation of, in part, large expectations, promises and visions about future usability; they also prompt initial and not infrequent controversial associations regarding institutional and organizational adjustments. These associations are refined or even revised through comparatively open search and experimentation processes. They are perpetuated over time in the form of new formative guiding principles for action that often clearly deviate from the earlier visions and expectations (Lente and Rip 1998; Bender 2006). Beyond this, they compete with existing and functioning technologies that will oftentimes also be developed further. Established technologies cannot simply be exchanged for new ones. The latter gain in terms of relevance by progressively developing beyond their established niches to become powerful alternatives. At this point they then change the technological profile of a sector through numerous search and selection processes (Levinthal 1998; Geels and Kemp 2007).

Furthermore, what is also typical, especially for new cross-sectional technologies, is that they sustain their dynamics after their formation and retain their fluid profiles. Even at the point, when they are already conveniently and economically utilized, they have not even finished developing. Consequently, they will continually be subject to substantial changes and further developments over a longer period of time (Freeman 1994). Emerging technologies are not characterized by singular closure processes that constitute a new and stable technological standard and path of development that could prevail as a reliable frame for socio-economic and institutional restructuring. In place of this, they are characterized by sustained technological dynamics, insecurities, and revisions, new opportunities and also surprising impasses. Under these conditions, technological lock-ins and path dependency (David 1985) are everything other than permanent and irreversible. Considerably more common today are temporary lock-ins that are activated and modified in rapid succession in response to technological developments (Beyer 2006).

This applies as well to *structural*, *institutional and organizational changes* that are influenced by new technological opportunities. Indeed, once again it is possible to identify historical turning points at which the socio-economic coordinates of a sector are called into question even though these had been stable over a longer period of time. For decades the IBM-dominated computer industry; the state-monopolistic structure of the telecommunication sector; the pharmaceutical sector oriented around chemicals; and the oligopolistically structured music industry were characterized by stable socio-technical arrangements that have eroded away with the emergence of fundamental new technological opportunities.

Technology-induced socio-economic change occurs, however, not in the form of drastic changes in the short term. In general, due to the configurative complexities of their structural, institutional and organizational arrangements established sectors exhibit a high level of stability and can only gradually be geared towards new (technological) conditions (North 1990; DiMaggio and Powell 1983; Hannan and Freeman 1984). More specific organizational restructuring, the building up of new business areas and large-scale repositioning in production, sales, or research and development that are triggered by new technological opportunities occur by degrees. Existing markets and competitive constellations do not change abruptly. New actors, who emerge on the fringes or who come from outside of a sector, oftentimes evolve quickly into serious challengers. They must, however, stabilize and reinforce their roles over time. Significant shifts in the actor and power figurations are not the result of singular disruptions, but take shape after sustained debates between interests and their struggles for influence. And even the institutionalization of a new field of technology, its regulatory architecture and the search for fitting legal and use frameworks is a time-consuming, voting-intensive process: it must be substantiated through complex processes of negotiation influenced by different interests and occurring between a large number of relevant actors (Mokyr 2002; Werle 2005).

Furthermore, corresponding adjustments are often not anticipatory, occurring in expectation of what technologies might emerge next—it is impossible to predict exactly what will come. They initially unfold in reaction to increasing and irrefutable technological pressures to change. And they do not occur sequentially, but are the subject of discussion, provoke controversial debates within society and become solidified in difficult and conflict-laden negotiations or through competitive processes between heterogeneous actors (Dolata 2009). Added to this, a sector in transition—with all of the adjustments that are taking place within it—cannot simply catch up with already stable and no longer questioned new technological circumstances. New technologies themselves are in a constant state of flux. Due to their development dynamics, they continually confront the affected sectors and their actors with new challenges over an extended period of time.

Even under massive pressure from new technological opportunities, processes of sectoral restructuring require time and are plagued by uncertainty due to indeterminate technological dynamics. In light of the extreme differences between the interests of the involved actors, these processes are in part contentious and hard-fought. This is especially clear in the complicated and drawn-out negotiation processes in which the legal-regulatory frameworks are brought into line with the new technological circumstances. This was evidenced with the formulation of genetic engineering laws in the 1980s and 1990s or with the reformulation of copyright regulations in response to digitalization and the Internet.

There is a system to this alleged paradox that leads to the *first specification*. Although larger socio-technical changes, such as the ones described here, generally take place with a pronounced dynamism, are accompanied by significant restructuring and exhibit radical results, they may still be reconstructed and reproduced fittingly as periods of gradual transformation. Hence, the development of new socio-technical realities is multi-phased and drawn-out over time in the face of various dynamics and pressures to change. Far-reaching changes to existing organizational structures, regulations and frameworks cannot be achieved overnight. Instead they are shaped by uncertain, initially experimental and contentious search, selection and restructuring processes. Through these they develop, over the course of time, significantly different technological, institutional and organizational architectures that structure the investigated fields in new ways.

4.2 Specification 2: Gradual Transformation as a Combination of Different Modes of Change

Nothing has been said up to this point about typical variants through which such periods of substantial change can actually come about. The five different modes of gradual transformation set forth by Kathleen Thelen and Wolfgang Streeck can be used as a starting point in order to detect such variants even in processes of technology-induced sectoral change; they must, however, correspond to both the subject matter and to one another.

When investigating technology-induced sectoral change, it initially appears that sectors featuring a limited receptiveness or adaptability are characterized early on by what would be known as *drift*. They exhibit an underdeveloped ability on the part of established actors and institutions to recognize and adapt when confronted with changing technological possibilities, coupled with a considerable amount of resistance towards change. The existing structures, institutions and actors get by in times of crises by acting hesitantly or by remaining inactive and thereby sacrificing their importance. This behavior opens up room to maneuver for alternatives or for new actors who push their way into the sector and drive restructuring forward. In an extension upon the typology of modes of change by Thelen and Streeck, the latter can be labeled *expansion*: a proactively driven assimilation and development of new technological opportunities and the associated formation of new, related milieus of actors with their own interests, strategies, institutions and structures.

During the core phase of a period of (sectoral) transformation new technological opportunities achieve a level of relevance that is no longer to be denied, and essential structural, institutional and organizational changes are carried out. This core phase is influenced in a fundamental way by the first three described mechanisms of gradual change. Thus it is shaped by the gradual redefinition of organizational plans of action, collective rules and leading sectoral principles (*conversion*); through significant

shifts in the figuration of actors, patterns of competition and cooperation, and power relationships that have shaped the sector up until that time (*displacement*); and/or through the realignment of existing structures, institutions and organizations as defined by extension to include new elements (*layering*). Finally, such transformations are always accompanied by—sometimes more intensely, sometimes more moderately—the decline of existing structural elements, institutions and organizations, which have become obsolete over the course of the transformation and which eventually disappear (*exhaustion*).

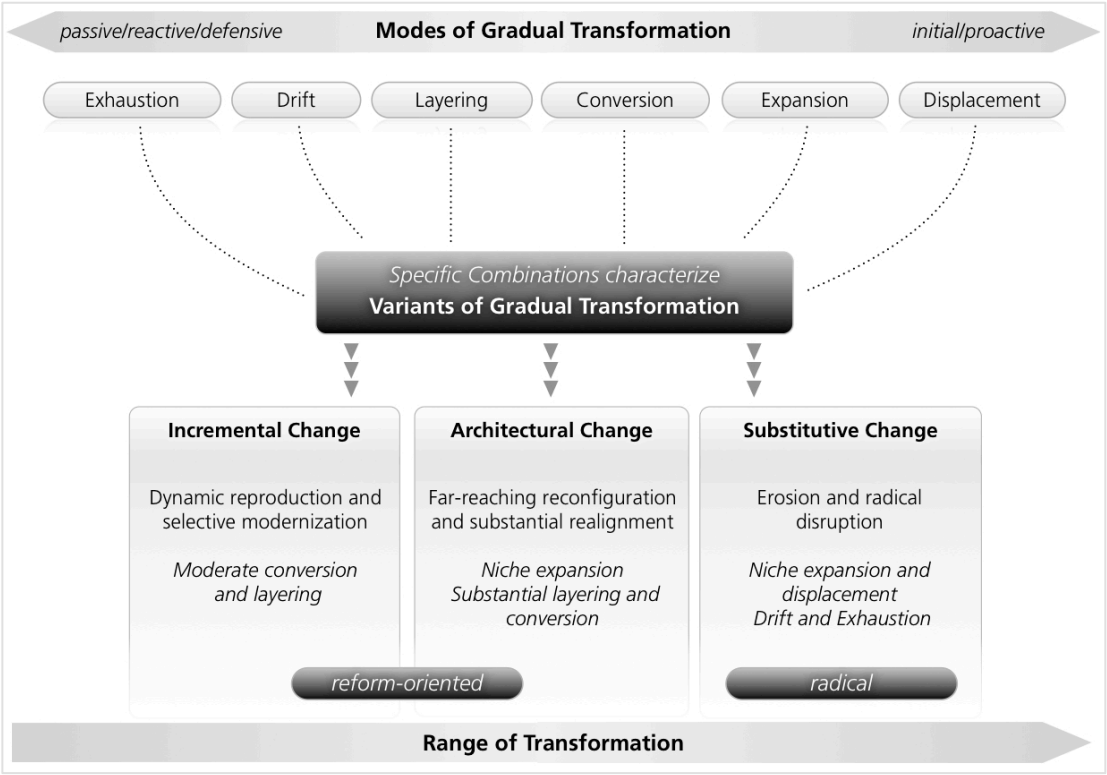
The above has already shown that singular modes of change, taken on their own, only represent different opportunities by which the processes of gradual transformation can be solidified. They are, however, incapable of characterizing a period of transformation in general, nor can they provide detailed definitions of types and variants of such transformation processes. It is highly unlikely that a period of transformation that extends over one or two decades could really be shaped or significantly influenced by one of the aforementioned modes alone. The institutional and organizational fields are too complex, the actors who are involved are too heterogeneous and the transformation process itself is too erratic and fragmented. Fundamentally more likely is that such periods of substantial change receive their characteristic signature primarily through specific *combinations of different modes of gradual transformation*.

The case of the transformation of the music industry is a very blatant example. It does not allow itself to be characterized by a dominant mode—such as *displacement, layering* or *conversion*. By contrast, it is shaped by different modes that function at times in a complementary manner and in others in a conflicting way. These are introduced by different actors who display clear preferences for respective modes. Sectoral transformation is not only influenced by radical challenges to the established institutions and organizations within a field, but also by the development or expansion of fundamental institutional and organizational alternatives to the conventional music business. It is also characterized by attempts from the established core to use moderate institutional and organizational changes in order to absorb the shocks caused by the new technologies; such attempts may include amendments to the existing institutional framework or the extension of traditional areas of business by new ones.

Generally speaking: elongated realignments of complex socio-technical fields, such as that discussed here, are characterized during a period of transformation by the formation and encroachment of feasible alternatives (*expansion* and *displacement*); by substantial additions (*layering*); and also by targeted modifications to the existing organizational structures and patterns of regulation (*conversion*). Moreover, these are regularly accompanied by decreases in importance or the decline of organizations and institutional segments that lack adaptability (*drift and exhaustion*). The mixture is what counts: an overall picture and hallmark of a period of transformation are first formed through the weighting and distinct combination of different modes of change (*Figure 1*).

Therefore, the *second specification* should be noted as: in each period of substantial change different modes of gradual transformation mix and interlock in specific ways. They first form distinct variants or patterns of transformation via their specific weighting and combination. In other words: In order to specify the characteristics of a period of change the formative modes of gradual transformation have to be identified, weighted and correlated dynamically on a case-by-case basis.[3]

Figure 1: Modes and Variants of Gradual Transformation



[3] Even James Mahoney and Kathleen Thelen (2010: 15) attempt to identify different types of institutional change—and refer in their explanation to two, in their opinions, relevant contextual prerequisites for change. These prerequisites are: the political framework, under which such change occurs, and the characteristics of the institution that is (currently) under pressure to change. "Here the characteristics of both the political context and the institution in question together drive the type of institutional change we can expect. Political context and institutional form have these effects because they shape the type of dominant change-agent that is likely to emerge and flourish in any specific institutional context, and the kinds of strategies this agent is likely to pursue to effect change". For these authors the outlined modes of gradual transformation are indeed the basic types of institutional change—they therefore do not attempt to combine different modes with one another. Beyond this the authors concentrate on identifying the actors, who support and drive change (change-agents)—and in doing so leave unnoticed all of those actors who attempt to block, circumvent or to channel processes of change in their fields.

4.3 Specification 3: Variants of Gradual Transformation

The conditions that leave their mark on a period of transformation can vary greatly depending on which technology or sector is being considered. Consequently, such periods, their progression and results are significantly differentiated from one another under the basic premise that even radical change typically evolves from a multitude of gradual transformations. This raises the question of distinct variants of gradual transformation, each with characteristic features. I will present four of them within the *third specification* as stylized types.

Variant 1: Dynamic Reproduction and Incremental Change

The first variant falls outside of the boundaries of radical socio-technical change. It is characteristic of the impact of new basic technologies that display relatively low transformative capacity within a sector. In this case, new technological opportunities resemble incremental innovations that, in part, sustainably improve on existing processes and products without necessitating larger socio-technical revisions or restructuring. The pressure to adapt and to change is accordingly moderate. This applies, for example, to the opportunities for usage and for the integration of Internet-based technologies within the production and cooperation structures of the automotive sector.

In such cases it is possible to analyze the process of introduction of new technologies as one of incremental implementation and extensive integration into existing organizations, rules and structures that—at their core—are not up for consideration. This process is largely supported by the established actors within the sector and takes place largely within the frame of the existing institutions and structures. It is characterized by *moderate conversion and layering*, especially concerning (inter-)organizational structures that are pursued with the goal of modernization and improvements in efficiency.

Even these sorts of modernization projects are in no way trivial processes. This is evidenced by the changeover from electronic-data-interchange-systems to Internet-based communication structures in the automotive sector (e-business watch 2005). Such projects are time consuming, elaborate and require a great deal of organization as well as often demanding high investment levels. They also naturally involve perceivable changes; otherwise they would not be undertaken. Such changes aim however not at radical sectoral transformation, but at “performance improvements” (Geels and Kemp 2007: 445). These are also typical for incremental innovation outcomes.

To that effect, the first variant of gradual transformation can be described as a process of *dynamic reproduction and incremental change*. Its appearance is essentially controlled by established actors and occurs within existing socio-technical arrangements that maintain largely stable frameworks.

Variant 2: Substantial Realignment and Architectural Change

This is different in the case of the second variant. It is typical for the diffusion of new crossover technologies with transformative capacities within adaptable sectors. That is to say: new technological opportunities have an enormous potential in terms of sectoral development and application, and this potential can be realized only through substantial organizational, structural and institutional changes. In its initial phase, the transformation process is often shaped by the impulses that it receives from the fringes of or even from outside of a sector. Actors that are either new or external to the field trigger these impulses. But, even the established actors within a sector are adaptive in such instances. Even if they are not among the early adopters of the new technologies, they actively pick up on their opportunities, reorient their activities accordingly and adjust their research, production and organizational structures to fit with the changed conditions. This is what I refer to as high adaptability on the part of the sector and its established actors who have been placed under pressure to change (Dolata 2009). The transformation of the pharmaceutical sector that was triggered by genetic engineering in the US between the middle of the 1970s through to the middle of the 1990s is just such a case (Henderson et al. 1999; Barben 2007).

Under such conditions, the process of transformation is shaped significantly by *substantial and orderly layering and conversion*. These affect the technological profile, the organizational structures and the interorganizational relations, the products and markets, the sectoral structures and the institutional framework. The technological profile of the sector changes with time and these changes occur above all through niche expansion, layering and recombination. Established technologies are not displaced but are (re-)combined with new opportunities. The spectrum of actors expands out to include new actors that are not just responsible for sending important impulses for sectoral change during the initial phase of emergence of new technological opportunities; they are also active during the institutionalization of new socio-technical realities. New forms of interorganizational cooperation are tested, stabilize with time and end up integrating newcomers into the realignment of the sector. The direction and method of operation utilized in research and development is realigned. Established products and markets are not just simply replaced, in time they are in fact expanded upon to include new variants and segments. In the long run even the legal-regulatory framework is gradually adjusted to fit with the new socio-technical realities. Nor do these occur in a single attempt; just the opposite, they are multi-staged and, given the sustained innovation dynamics, occur over an extended period of time.

Other modes of sectoral change play, by comparison, a limited role. Above all, due to the adaptive orientation of the established actors of the field, *drift*, *exhaustion* as well as crisis-laden change remain fringe phenomena of the transformation process.

A radical exchange and *displacement* of existing actors, institutions and structures is largely unusual for this variant of gradual transformation.

Altogether, it is possible to describe the transformation process in this case as a *substantial realignment and architectural change*, over the course of which the existing socio-technical arrangements of a sector are not replaced by fundamentally new arrangements. They are instead effectively expanded upon and (re-)combined with new elements: "New regimes grow out of old regimes through cumulative adjustments and reorientations" (Geels and Schot 2007: 407). The newly created socio-technical constellations challenge the established core of the sector, yet without being able to disrupt and largely replace the supporting actors, institutions and structures.

Variant 3: Disruption, Erosion and Substitutive Change

The third variant of gradual transformation is, by contrast, typical for sectors that are incapable of adapting: their established actors and institutions that are confronted by technologies with great transformative capacities are resistant to change. The exemplary case of the Internet's infiltration of the music industry can be cited here as evidence (Dolata 2011).

What is typical here is for new technologies to come from outside or from the fringes of a sector. Similar to the just described variant, they have great transformative capacity and are comparatively easy to utilize and develop further—regardless of by whom. The existing technological profile of a sector is susceptible from the very beginning when faced with fundamental innovations. But at this point new technological opportunities collide with established actors and institutions that are incapable of adapting. Thus, actors that are resistant to change, and the institutional arrangements within which they are active, quickly lose control over the transformation process. Adoption, utilization and commercialization are thereby left to newcomers, who then not only trigger sectoral change, but can also shape its further progress.

Under these conditions, sectoral transformation is driven not just through its initial phase, but also beyond that by the *expansion* of new actors with individual interests and plans of action. They constitute their own structures and regulations, which stand in opposition to the established ones (Leblebici et al. 1991; Flowers 2008). They aim, more or less consciously, to achieve a far-reaching exchange and *displacement* of the institutions and organizations that had previously shaped the sector. In contrast, saturated actors at first refuse to play an active role, attempting instead to block the new developments and reacting only belatedly with forms of moderate modernization that conform to the existing system. They *drift* at first inactive through unfamiliar situations that they are unable to control. They make an effort to catch up through *moderate adaptations, layering and conversion* to reclaim a place for their existing organizational profile and institutional framework. The established actors, institutions and

structures become significantly less important in the process of this confrontation between radical and moderate changes. This is mainly due to their adaptation deficits with regard to the disruptive potential of the new technologies.

In this variant the new technologies, products, markets, actors, patterns of interaction and regulation also gradually become visible. They are also at first overshadowed by the pre-existing and still functioning constellations. However, they quickly gain importance, promote the creation of self-contained regulations and structures and—this is the difference when compared to the second variant—resist being embedded in the existing sectoral context via selective and orderly adjustments. By contrast, they quickly enter into an antagonistic and substitutive competition with the established sectoral context. Due to the increasing predominance of and acceptance for the new technologies, as well as the inability of the old core of the sector to adapt, in the course of the transformation this leads to radically new realignments and a reweighting of the actor figurations, institutions and structures of the sector as a whole.

In comparison to the second variant of gradual transformation, this one is characterized by the fact that constitutive elements of the organizational and institutional structures erode over time, become obsolete (*exhaustion*) and are progressively replaced by new actors, patterns of interaction, institutions and structures (*displacement*). This can be termed *disruption, erosion and substitutive change*.

Variant 4: Enduring Coexistence, Substitutive or Architectural Change

Typical for the fourth and final variant is an initial combination of high technical and social stability and persistence. In its shadows, an alternative socio-technical path—with its own structural features, rules and actors—gradually unfolds. It does not, however, quickly develop into an existential challenge to the established core of the sector. It evolves over a longer period of time independent of and yet parallel to the established path (Braun-Thürmann 2005: 46–51; Kemp et al. 2001). This mainly applies to the tightly knit networks and the capital- and organization-intensive infrastructures of large technical systems that are, for example, still to be found today in the German energy sector (Voß and Bauknecht 2007; Mautz et al. 2008; Praetorius et al. 2008). The more intensive the organizational needs and the more complex and empowered a socio-technical system's structures are, the more demanding and protracted the radical transformation will be.

In such cases, processes of sectoral transformation will be affected by niche dynamics for a long period of time. During this time they will develop an alternative socio-technical path parallel to and independent of the existing system's structures. The development of this path will oftentimes be aided and shielded by political protections and interventions—such was the case with renewable energies in Germany. The dominant form of change in this phase can be called *expansion* of a niche. Yet, at this

stage it does not initially challenge nor call into question the dominance and the functional logic of the existing sector's core structures. At the beginning it forms a type of coexistence that is asymmetrically composed between different development paths that have little in common and notably exist independent of one another. This asymmetrical coexistence may first then develop into an antagonistic coexistence when the niche develops into a functioning and widely accepted socio-technical alternative that is large enough to be relevant to the market.

Further along the transformation process, which is characterized by an increasing direct rivalry between the core and the emancipated niche, there are two different potential development paths.

Coexistence can merge into a process of *substitutive change*—this is the radical avenue. In this case the dominant socio-technical system and its actors come under pressure not only due to the superior and expanding technological alternatives, but also due to corresponding political or societal preferences and options. The pressure exerted is so great that its legitimacy and authority to function erode. *Exhaustion* of the dominant technologies and their supporting institutions and actors accompanies their own gradual *displacement* via a substantial new socio-technical constellation—with a new technological basis, other institutions and new or strategically and fundamentally reoriented actors that support them.

Also conceivable, and in no way less plausible, is a course of transformation that can, by contrast, be categorized once again as *architectural change*. In such instances where the established core of the sector has been placed under pressure, it will seek to adapt new technological opportunities that have established their own niche and become stable. The existing socio-technical constellation does not disintegrate; instead it expands substantially through the selective absorption and embedding of alternative technological opportunities (*substantial layering*) and is selectively altered (*selective conversion*). *Substantial layering* and *selective conversion* signify that with the transformation new markets (and sub-segments) arise, the product portfolio is broadened, organizational structures are arranged accordingly and existing institutional arrangements are fitted to the changed socio-technical conditions. Even the changes linked to this can become far-reaching over time. They certainly do not mark a radical break with the existent technologies, institutions and actors of a sector; in lieu of this they target its reform and reconfiguration.

In each case a particularly drawn-out process of gradual transformation characterizes this variant. This applies both to the phase of niche growth amongst technological alternatives as well as to the phase of their antagonistic coexistence with already existing socio-technical constellations.

5 Gradual Transformation as a Pragmatic Research Approach

With the concept of gradual transformation presented here it is possible to more precisely analyze the concrete processes and variants of larger socio-technical changes, which initially were somewhat vaguely referred to as "periods of mismatch" (Dosi et al. 1988: 11) or even as a "period of considerable confusion" (Henderson and Clark 1990: 12). The lid has been pried off of the *black box*: the specific influencing factors, processes and dynamics of such periods of transformation are now the topics of inquiry. They must no longer only be identified as protracted, often disputed and competitive search, selection and realignment processes; on the contrary, they can be precisely reconstructed and categorically represented. They are distinguished by:

- The measured diffusion of new technologies, whose features may still be subject to drastic changes during the course of the transformation process;
- The successive formation of new markets and non-market relations, patterns of competition and cooperation along these lines;
- The gradual modernization of the structures and institutional arrangements of the investigated field; as well as
- The accompanying changes amidst the pre-existing actor figurations, and relations of power and influence.

Transformation means: change resulting in the radical realignment of a field, by which both its technological profile and the connected social coordinates are significantly modified. *Gradual*, on the other hand, emphasizes the fundamental procedural peculiarity of such changes, which essentially occur by degrees as an accumulation of numerous transformation-related impulses extending over a longer period of time.

Admittedly, the concept that is proposed here goes well beyond the general statement that substantial socio-technical change is typically implemented in the form of a gradual transformation. It provides concrete tools for analyzing and classifying such exceptional periods of change. Examining relevant combinations of different modes of gradual transformation allows for the delineation of distinct development paths and for the identification of common patterns of socio-technical change. It is then possible to distinguish between two ideal types of combinations that shape the process of transformation in differing ways.

The *first combination* is *layering–conversion*. Even if the essential impetus for change comes from outside of or from the fringes of the sector, its established core acts upon it relatively early and proactively. The process of transformation occurs mainly via strategic realignments of established actors, as a significant expansion and reorganization of already existing patterns of organizations, institutions and structures into which new elements and actors are integrated. These are then combined in new ways with those that are still in existence. This is the *reform-oriented variation*

of gradual transformation, that does not result in disruptive substitutions, but instead—depending on the transformative capacity of the new technologies—in incremental adaptations or broader architectural changes. This is typical for sectors with high adaptability concerning new technological challenges.

The alternative to this is the *second combination*, *expansion–displacement*. Established actors' difficulty in accepting fundamental new technologies, taking them up and adapting them corresponds, in this case, to a significant increase in the importance of new and innovative actors. These innovators are responsible not only for driving change forward through their activities in the initial phase of transformation; they are also essential supporters and impulse providers throughout the whole period of transition. Their expansion is accompanied by the installation of alternative regulatory patterns and structures, which stand at odds to and in competition with the already existing ones. These are gradually destabilized and, with time, extensively replaced. This is the *radical variation of gradual transformation* that results in the wide-ranging erosion and substitution of existing organizations, structures and institutions and which is typical for sectors that are incapable of adapting.

The *third combination*, *drift–exhaustion* can be found in both variations of gradual transformation, but there it exhibits differing characteristics. It is essential for the radical one. Expansion to include new actors and the formation of alternative institutional arrangements and structures is associated with the inability of established actors and institutions to adapt. The existing institutions and structures become obsolete and are gradually replaced during the transformation process. This is the only way in which *exhaustion*, that is obsolescence and disintegration, makes any sense as a distinct mode of change: supporting institutions, structures and actors only become superfluous when there are new ones ready to replace them.

The reform-oriented variation of gradual transformation is also associated with the decline of individual actors, who cannot withstand the pressure to change, and with sectoral processes of modernization. This causes portions of the existing institutions and structural arrangements to decrease in importance and eventually to be replaced. However in this variation, this is a side effect that occurs alongside the architectural changes that are brought about by the modernization and conversion processes of the existing arrangements. Naturally, in this environment individual areas of regulation and structural elements are also allowed to fail and be replaced.

All of the modes and ideal-types of combinations of gradual change that have been presented here can be identified periodically during concrete processes of socio-technical transformation. Nevertheless, each exhibits a different mix and weighting. The reform-oriented variation that is characterized by layering and conversion is also influenced by expansion to include new actors and by the partial replacement of existing rules and structural elements. Conversely, there are always attempts within the

radical variation that aim to stem or channel erosion processes through moderate modernization initiatives.

One consideration should be added. When substantial changes are typically understood as the result of gradual and cumulative processes, then it is of course necessary to clarify what distinguishes gradual transformation from dynamic reproduction—"in other words, where flexible reproduction through adaptation ends and the replacement of one social order with another begins" (Streeck 2009: 16). When do such processes of gradual transformation transition into new systemic qualities? When do the many technological and socio-economic changes really become substantial and replace those "cumulative commitments" (Pierson 2000: 76), which have defined the sector up to that point by guaranteeing its stability and reproduction?

Although important, these questions are admittedly difficult to answer. While it is possible to demarcate, with relative clarity, the beginning of a period of socio-technical change, identifying clear-cut turning points within the course of a transformation process is much harder. The essential feature of gradual transformation is exactly that new and substantially different sectoral conditions and actors do not emerge abruptly and in the short term. The opposite is true; they emerge by degrees, as an accumulation of numerous events that stabilize only in time. Even exogenous shocks—such as the intrusion of the Internet into the, until that time, rigid world of the music industry—are just the starting points for longer-lasting periods of change.

None of this alters the fact that within the process of gradual transformation important sectoral coordinates are markedly shifted. With time these form a new supportive structure for the sector. But at what point can this be said to be the case? Generally speaking, this occurs when both the technological profile of the sector and its socio-economic foundations—its actors, institutions and structures—are not only substantially modified, but, going beyond this, have become stabilized as new socio-technical realities. They are no longer reversible, constitute new guiding principles for the sector's actors and have become essential for the sector's future reproduction. This is the point when one can speak of a *relative stabilization of a new or rather newly arranged sectoral regulation structure*.

For this to happen, the old technologies do not have to be replaced by the new ones. But the new ones must have solidified themselves as unavoidable realities within a sector. On a case-by-case basis and with different weighting, this means:

- They have established themselves as the indispensable basis of new methods of research, production processes or sales structures, without which the reproduction of the sector would no longer be guaranteed;
- They have freed themselves from the constraints of the experimental niches by providing new offerings, have become firmly established on the market with a

relevant portion of the earnings and determine the future structuring and dynamics of the sectoral markets;

- They exert a significant amount of influence on the structuring of private demand and consumption patterns.

In addition, the search for fitting patterns of organization, interaction and regulation must be so advanced that, as a result, binding and behavior-forming socio-economic frameworks have become institutionalized. Once institutionalized, they cannot simply be reversed and dissolved. Among these are (once again with different specifications on a case-by-case basis):

- The establishment of new sectoral actors, that have become liberated from a niche existence, have become solidified as constitutive elements of the newly structured field and claim to be responsible for innovation processes;
- The consolidation of modified patterns of organization aligned with the new technologies pushed through by the remaining traditional actors who have largely completed their processes of realignment and reorganization;
- The stabilization of innovative, previously non-existent competitive and cooperative relations between actors, that regulate the exchange between them not just occasionally, but instead have become essential in nature;
- Finally the institutionalization of considerably different regulations—rules, norms and standards—that structure behavior against a new background and from now on influence the conditions for reproduction of the affected sector.

Such a turning point was reached in the pharmaceutical sector, for example, in the middle of the 1990s. Pharmaceutical research and development were no longer imaginable without the essential contributions made by new biotechnological methods. Biotechnology companies had established themselves as a new type of company within the sector and had expanded the organizational field respectively. New modes of cooperation between the large pharmaceutical companies, biotechnology start-ups and research institutions had become patterns of interaction that were unavoidable. The further development of the pharmaceuticals market had come to be characterized by genetically engineered medications, vaccines and diagnostic products. Even a new legal-regulatory framework pertaining to research and production involving genetic engineering was formed not just in the national context but also within the contexts of European and international regimes (Dolata 1996, 2003; Barben 2007).

Relative stabilization of a new pattern of sectoral regulation therefore does not necessarily signal the replacement of older with newer technologies and the displacement of old actors, patterns of interaction, institutions and structures with new ones. What is decisive is that in the course of the gradual transformation both the stage of development and utilization of the new technologies as well as the accompanying socio-economic restructuring efforts are so advanced and stabilized, that they shape the

conditions and orientation within the sector and its further development dynamics. In addition, relative stabilization also refers to a process of transformation that is not necessarily complete upon reaching just such a turning point. Considering the oftentimes sustained technological dynamics, stabilization amidst a new sectoral structuration does not have to mean that it will lead to a new phase of continuity with a limited amount of modification and detailed adjustments. Temporary stabilization can generate a new starting point for a further round of gradual transformation, which once again leads to major changes within the sector. Whether that occurs—this is one of the many empirical questions that have to be tested and answered on the basis of concrete examples.

References

Bandelow, Nils, 1999: *Lernende Politik. Advocacy-Koalitionen und politischer Wandel am Beispiel der Gentechnologiepolitik*. Berlin: Edition Sigma.

Barben, Daniel, 2007: *Politische Ökonomie der Biotechnologie. Innovation und gesellschaftlicher Wandel im internationalen Vergleich*. Frankfurt/New York: Campus.

Bender, Gerd, 2006: *Technologieentwicklung als Institutionalisierungsprozess. Zur Entstehung einer soziotechnischen Welt*. Berlin: Edition Sigma.

Beyer, Jürgen, 2006: *Pfadabhängigkeit. Über institutionelle Kontinuität, anfällige Stabilität und fundamentalen Wandel*. Frankfurt/New York: Campus.

Braun-Thürmann, Holger, 2005: *Innovation*. Bielefeld: Transcript.

Bresnahan, Timothy F./Franco Malerba, 1999: Industrial Dynamics and the Evolution of Firms' and Nations' Competitive Capabilities in the World Computer Industry. In: Mowery, David C./Richard R. Nelson (eds), *Sources of Industrial Leadership. Studies of Seven Industries*. Cambridge: Cambridge University Press, 79–132.

Bundesverband Musikindustrie (eds), 2010: *Jahreswirtschaftsbericht 2009*. Berlin: Bundesverband Musikindustrie.

Burkart, Patrick/Tom McCourt, 2006: *Digital Music Wars. Ownership and Control of the Celestial Jukebox*. Oxford: Rowman & Littlefield.

Campbell, John L., 2004: *Institutional Change and Globalization*. Princeton: Princeton University Press.

Campbell, John L., 2006: What's New? General Patterns of Planned Macro-institutional Change. In: Hage, Jerald/Marius Meeus (eds), *Innovation, Science, and Institutional Change*. Oxford: Oxford University Press, 505–524.

Currah, Andrew, 2006: Hollywood Versus the Internet: The Media and Entertainment Industries in a Digital and Networked Economy. In: *Journal of Economic Geography* 6, 439–468.

Currah, Andrew, 2009: *What's Happening to Our News. An Investigation into the Likely Impact of the Digital Revolution on the Economics of News Publishing in the UK*. Oxford: Reuters Institute.

David, Paul A., 1985: Clio and the Economics of QWERTY. In: *American Economic Review* 75, 332–337.

DiMaggio, Paul. J./Walter W. Powell, 1983: The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. In: *American Sociological Review* 48, 147–160.

Djelic, Marie-Laure/Sigrid Quack (eds), 2003: *Globalization and Institutions. Redefining the Rules of the Economic Game*. Cheltenham: Edward Elgar.

Djelic, Marie-Laure/Sigrid Quack, 2007: Overcoming Path Dependency: Path Generation in Open Systems. In: *Theory and Society* 36, 161–186.

Dolata, Ulrich, 1992: *Weltmarktorientierte Modernisierung. Die ökonomische Regulierung des wissenschaftlich-technischen Umbruchs in der Bundesrepublik*. Frankfurt/New York: Campus.

Dolata, Ulrich, 1996: *Politische Ökonomie der Gentechnik. Konzernstrategien, Forschungsprogramme, Technologiewettläufe*. Berlin: Edition Sigma.

Dolata, Ulrich, 2003: *Unternehmen Technik. Akteure, Interaktionsmuster und strukturelle Kontexte der Technikentwicklung: Ein Theorierahmen*. Berlin: Edition Sigma.

Dolata, Ulrich, 2007: 25 Jahre kommerzielle Gentechnik. In: *Blätter für deutsche und internationale Politik* 52, 1395–1397.

Dolata, Ulrich, 2009: Technological Innovations and Sectoral Change. Transformative Capacity, Adaptability, Patterns of Change. An Analytical Framework. In: *Research Policy* 38, 1066–1076.

Dolata, Ulrich, 2011: *The Music Industry and the Internet. A Decade of Disruption and Uncontrolled Sectoral Change*. Stuttgart: University of Stuttgart, Institute for Social Sciences.

Dosi, Giovanni/Christopher Freeman/Richard Nelson/Gerald Silverberg/Luc Soete (eds), 1988: *Technical Change and Economic Theory*. London/New York: Pinter.

Drews, Jürgen, 1999: *In Quest of Tomorrow's Medicines*. New York: Springer.

e-business watch (eds), 2005: *ICT and Electronic Business in the Automotive Industry. ICT Adoption and E-business Activity in 2005*. Berlin/Brussels: European Commission.

e-business watch (eds), 2005a: *ICT and Electronic Business in the Publishing & Printing Industry. Key Issues and Case Studies.* Luxembourg: European Commission.

Flowers, Stephen, 2008: Harnessing the Hackers: The Emergence and Exploitation of Outlaw Innovation. In: *Research Policy* 37, 177–193.

Freeman, Christopher, 1994: The Economics of Technical Change. In: *Cambridge Journal of Economics* 18, 463–514.

Freeman, Christopher/Carlota Perez, 1988: Structural Crises of Adjustment, Business Cycles and Investment Behaviour. In: Dosi, Giovanni/Christopher Freeman/Richard Nelson/Gerald Silverberg/Luc Soete (eds): *Technical Change and Economic Theory*. London/New York: Pinter, 38–66.

Geels, Frank W./Johan Schot, 2007: Typology of Sociotechnical Transition Pathways. In: *Research Policy* 36, 399–417.

Geels, Frank/René Kemp, 2007: Dynamics in Socio-technical Systems: Typology of Change Processes and Contrasting Case Studies. In: *Technology in Society* 29, 441–455.

Greenwood, Royston/C.R.Hinings, 1996: Understanding Radical Organizational Change: Bringing together the Old and the New Institutionalism. In: *The Academy of Management Review* 21, 1022–1054.

Hall, Peter A./Kathleen Thelen, 2009: Institutional Change in Varieties of Capitalism. In: *Socio-Economic Review* 7, 7–34.

Hannan, Michael T./John Freeman, 1984: Structural Inertia and Organizational Change. In: *American Sociological Review* 49, 149–164.

Henderson, Rebecca/Kim B. Clark, 1990: Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Existing Firms. In: *Administrative Science Quarterly* 35, 9–30.

Henderson, Rebecca/Luigi Orsenigo/Gary P. Pisano, 1999: The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions Among Scientific, Institutional, and Organizational Change. In: Mowery, David C./Richard R. Nelson (eds), *Sources of Industrial Leadership. Studies of Seven Industries*. Cambridge: Cambridge University Press, 267–311.

IFPI (eds), 2009: *Digital Music Report 2009*. London: IFPI.

IFPI (eds), 2011: *Digital Music Report 2011*. London: IFPI.

Kemp, René/Arie Rip/Johan Schot, 2001: Constructing Transition Paths Through the Management of Niches. In: Garud, Raghu/Peter Karnoe (eds), *Path Dependence and Creation*. Mahwah/London: Lawrence Erlbaum, 269–299.

Kenney, Martin/James Curry, 2001: The Internet and the Personal Computer Value Chain. In: BRIE-IGCC E-conomy Project (eds), *Tracking a Transformation. E-commerce and the Terms of Competition in Industries.* Washington D.C.: Brookings Institution Press, 151–177.

King, Roger, 2007: *The Regulatory State in an Age of Governance. Soft Words and Big Sticks*. Hampshire/New York: Palgrave MacMillan.

Kitschelt, Herbert, 1991: Industrial Governance Structures, Innovation Strategies, and the Case of Japan: Sectoral or Cross-National Comparative Analysis? In: *International Organization* 4, 453–493.

Krasner, Stephen D., 1988: Sovereignty: An Institutional Perspective. In: *Comparative Political Studies* 21, 66–94.

Küng, Lucy/Robert G. Picard/Ruth Towse (eds), 2008: *The Internet and the Mass Media*. London: SAGE.

Leblebici, Huseyin/Gerald R. Salancik/Anne Copay/Tom King, 1991: Institutional Change and the Transformation of Interorganizational Fields: An Organizational History of the U.S. Radio Broadcasting Industry. In: *Administrative Science Quarterly* 36, 333–363.

Lente, Harro van/Arie Rip, 1998: The Rise of Membrane Technology: From Rhetorics to Social Reality. In: *Social Studies of Science* 28, 221–254.

Levinthal, Daniel A., 1998: The Slow Pace of Rapid Technological Change: Gradualism and Punctuation in Technological Change. In: *Industrial and Corporate Change* 7, 217–247.

Mahoney, James/Kathleen Thelen, 2010: A Theory of Gradual Institutional Change. In: Mahoney, James/Kathleen Thelen (eds), *Explaining Institutional Change: Ambiguity, Agency, and Power*. Cambridge: Cambridge University Press, 1–37.

Mautz, Rüdiger/Andreas Byzio/Wolf Rosenbaum, 2008: *Auf dem Weg zur Energiewende. Die Entwicklung der Stromproduktion aus erneuerbaren Energien in Deutschland*. Göttingen: Universitätsverlag Göttingen.

Mayntz, Renate, 2009: The Changing Governance of Large Technical Infrastructure Systems. In: Mayntz, Renate (ed): *Über Governance. Institutionen und Prozesse politischer Regulierung*. Frankfurt/New York: Campus, 121–150.

Mokyr, Joel, 2002: Innovation in an Historical Perspective: Tales of Technology and Evolution. In: Steil, Benn/David G. Victor/Richard R. Nelson (eds), *Technological Innovation and Economic Performance*. Princeton/Oxford: Princeton University Press, 23–46.

North, Douglass C., 1990: *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

OECD (eds), 2010: *The Evolution of News and the Internet*. OECD: DSTI/ICCP/IE(2009)14/FINAL.

Peitz, Martin/Patrick Waelbroek, 2006: Digital Music. In: Illing, Gerhard/Martin Peitz (eds), *Industrial Organization and the Digital Economy*. Cambridge/London: MIT Press, 71–144.

Pempel, T.J., 1998: *Regime Shift: Comparative Dynamics of the Japanese Political Economy*. Ithaca: Cornell University Press.

Pierson, Paul, 2000: Not Just What, but When: Timing and Sequence in Political Processes. In: *Studies in American Political Development* 14, 72–92.

Praetorius, Barbara/Dierk Bauknecht/Martin Cames/Corinna Fischer/Martin Pehnt/Katja Schumacher/Jan Peter Voß, 2008: *Innovation for Sustainable Electricity Systems. Exploring the Dynamics of Energy Transitions*. Dordrecht: Springer.

Quack, Sigrid, 2005: Zum Werden und Vergehen von Institutionen—Vorschläge für eine dynamische Governanceanalyse. In: Schuppert, Gunnar Folke (ed), *Governance-Forschung. Vergewisserung über Stand und Entwicklungslinien*. Baden-Baden: Nomos, 346–370.

RIAA, 2010: *2009 Year-End Shipment Statistics*. New York: RIAA.

Riehm, Ulrich et al., 2003: *E-Commerce in Deutschland. Eine kritische Bestandsaufnahme zum elektronischen Handel*. Berlin: Edition Sigma.

Rip, Arie/René Kemp, 1998: Technological change. In: Rayner, Steve/Elizabeth L. Malone (eds): *Human choice and climate change. Volume two: Resources and technology*. Columbus: Batelle Press, 328–399.

Rodriguez, Tina/Michael von Rothkirch/Oliver Heinz (eds), 2007: *www.musikverkaufen.de. Die digitale Musikwirtschaft*. München: Musikmarkt Verlag.

Roijakkers, Nadine/John Hagedoorn, 2006: Inter-firm Partnering in Pharmaceutical Biotechnology Since 1975: Trends, Patterns, and Networks. In: *Research Policy* 35, 431–446.

Schenek, Matthias, 1995: *Das Gentechnikrecht der Europäischen Gemeinschaft. Gemeinschaftliche Biotechnologiepolitik und Gentechnikregulierung*. Berlin: Duncker & Humblot.

Schneider, Volker, 2001: *Die Transformation der Telekommunikation: Vom Staatsmonopol zum globalen Markt (1800–2000)*. Frankfurt/New York: Campus.

Schrape, Jan-Felix, 2010: *Neue Demokratie im Netz? Eine Kritik an den Visionen der Informationsgesellschaft*. Bielefeld: Transcript.

Schrape, Jan-Felix, 2011: *Der Wandel des Buchhandels durch Digitalisierung und Internet.* SOI Discussion paper 2011-01. Stuttgart: Universität Stuttgart, Institut für Sozialwissenschaften.

Smith, Adrian/Andy Stirling/Frans Berkhout, 2005: The Governance of Sustainable Socio-technical Transitions. In: *Research Policy* 34, 1491–1510.

Streeck, Wolfgang, 2009: *Re-Forming Capitalism. Institutional Change in the German Political Economy*. Oxford: Oxford University Press.

Streeck, Wolfgang/Kathleen Thelen, 2005: Introduction: Institutional Change in Advanced Political Economies. In: Streeck, Wolfgang/Kathleen Thelen (eds), *Beyond Continuity. Institutional Change in Advanced Political Economies*, Oxford: Oxford University Press, 1–39.

Thelen, Kathleen, 2003: How Institutions Evolve: Insights From Comparative Historical Analysis. In: Mahoney, James/Dietrich Rueschemeyer (eds), *Comparative Historical Analysis in the Social Sciences*. Cambridge: Cambridge University Press, 208–240.

Tschmuck, Peter (2006): *Creativity and Innovation in the Music Industry*. Springer: Dordrecht.

Voß, Jan-Peter/Dierk Bauknecht, 2007: Der Einfluss von Technik auf Governance-Innovationen: Regulierung zur gemeinsamen Netznutzung in Infrastruktursystemen. In: Dolata, Ulrich/Raymund Werle (eds), *Gesellschaft und die Macht der Technik. Sozioökonomischer und institutioneller Wandel durch Technisierung*. Frankfurt/New York: Campus, 109–131.

Walgenbach, Peter/Renate R. Meyer, 2008: *Neoinstitutionalistische Organisationstheorie*. Stuttgart: Kohlhammer.

Werle, Raymund, 1990: *Telekommunikation in der Bundesrepublik. Expansion, Differenzierung, Transformation*. Frankfurt/New York: Campus.

Werle, Raymund, 2005: Institutionelle Analyse technischer Innovation. In: *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 57, 308–332.

Further Publications

Research Contributions to Organizational Sociology and Innovation Studies

Dolata, Ulrich, 2011: *The Music Industry and the Internet. A Decade of Disruptive and Uncontrolled Sectoral Change*. SOI Discussion Paper 2011-02.

Schrape, Jan-Felix, 2011: *Der Wandel des Buchhandels durch Digitalisierung und Internet*. SOI Discussion Paper 2011-01.

Books

Dolata, Ulrich, 2011: *Wandel durch Technik. Eine Theorie soziotechnischer Transformation*. Frankfurt/New York: Campus. (forthcoming)

Schrape, Jan-Felix, 2011: *Gutenberg-Galaxis Reloaded? Der Wandel des deutschen Buchhandels durch Internet, E-Books und Mobile Devices*. Boizenburg: Hülsbusch.

Schrape, Jan-Felix, 2010: *Neue Demokratie im Netz? Eine Kritik an den Visionen der Informationsgesellschaft*. Bielefeld: Transcript.

Journal Articles and Contributions in Edited Volumes

Dolata, Ulrich, 2011: Soziotechnischer Wandel als graduelle Transformation. In: *Berliner Journal für Soziologie* 21(2). (forthcoming)

Dolata, Ulrich, 2009: Technological Innovations and Sectoral Change. Transformative Capacity, Adaptability, Patterns of Change: An Analytical Framework. In: *Research Policy* 38(6), 1066–1076.

Dolata, Ulrich, 2008: Das Internet und die Transformation der Musikindustrie. Rekonstruktion und Erklärung eines unkontrollierten sektoralen Wandels. In: *Berliner Journal für Soziologie* 18(3), 344–369.

Dolata, Ulrich, 2008: Technologische Innovationen und sektoraler Wandel. Eingriffstiefe, Adaptionsfähigkeit, Transformationsmuster: Ein analytischer Ansatz. In: *Zeitschrift für Soziologie* 37(1), 44–61.

Fuchs, Gerhard, 2010: Path Dependence and Regional Development: What Future for Baden-Wuerttemberg? In: Georg Schreyögg/ Jörg Sydow (eds): *The Hidden Dynamics of Path Dependence. Institutions and Organizations*. Houndmills: Palgrave Macmillan, 178–196.

Fuchs, Gerhard/Sandra Wassermann, 2009: Picking a Winner? Innovation in Photovoltaics and the Political Creation of Niche Markets. In: *Science, Technology & Innovation Studies*, 4(2), 93–113.

Schrape, Jan-Felix, 2010: Web 2.0 und Massenmedien: Visionen versus Empirie. In: *Forschungsjournal Neue Soziale Bewegungen*, 23(3), 72–83.

Werle, Raymund (et al.), 2010: Software als Institution und ihre Gestaltbarkeit. In: *Informatik Spektrum* 31(6), 626–633.

Werle, Raymund/Jürgen Feick, 2010: Regulation of Cyberspace. In: Martin Cave/ Robert Baldwin/Martin Lodge (eds): *The Oxford Handbook of Regulation*. Oxford: Oxford University Press, 523–547.